

# ANALYSES AND OPTICAL PROPERTIES OF AMESITE AND CORUNDOPHILITE FROM CHESTER, MASSACHUSETTS, AND OF CHROMIUM-BEARING CHLORITES FROM CALIFORNIA AND WYOMING.

By EARL V. SHANNON,

*Assistant Curator, Department of Geology, United States National Museum.*

## INTRODUCTION.

The present paper records work done in the laboratory of the department of geology upon several chloritic minerals as part of a general, though interrupted, study of the complicated and imperfectly understood aggregation of substances commonly referred to collectively as the chlorite group. Previous work done by the present writer upon materials of this class has already been published, including analyses and optical properties of diabantite stilpnomelane and chalcodite from Westfield, Massachusetts,<sup>1</sup> stilpnomelane from Lambertville, New Jersey,<sup>2</sup> and prochlorite from Trumbull, Connecticut, and Washington, District of Columbia.<sup>3</sup> These investigations have not, as yet, furnished evidence upon which to base any new theoretical views as to the chemical nature of the various members of the group and discussion of the constitution either of the individual minerals or of the group as a whole is deferred until additional work shall have explained many points which are not now clear regarding variation in chemical composition and optical properties of the several constituents of the group. The work upon these minerals will be continued as good materials come to hand, or as the need for reinvestigating individual species becomes apparent.

## AMESITE FROM CHESTER, MASSACHUSETTS.

The name amesite was given by C. U. Shepard to a pale green chlorite occurring in intimate association with diaspore at the old emery mine in Chester, Massachusetts. The mineral which was analyzed by Pisani<sup>4</sup> is described as in hexagonal plates; foliated,

<sup>1</sup> Proc. U. S. Nat. Mus., vol. 57, 1920, pp. 397-403.

<sup>2</sup> Idem (in press).

<sup>3</sup> Idem (in press).

<sup>4</sup> Pisani, Compt. Rendus Acad. Sci., vol. 83, 1876, p. 166.

resembling the green talc from the Tyrol. Hardness 2.5-3.0; specific gravity 2.71; sensibly uniaxial, optically positive; color pale apple-green; luster pearly on the cleavage face. Composition approximating to  $H_4(Mg, Fe)_2 Al_2 SiO_9$ .

Tschermak<sup>1</sup> later assumed amesite to represent a fundamental end member, and explained the constitution of the orthochlorites by assuming them to be isomorphous mixtures of the amesite molecule and the serpentine molecule. Considerable interest thus attaches to the mineral which has been found only at this exhausted locality. Since no other analysis of amesite than that of Pisani appears to have been made and in order to determine the refractive indices on analyzed material, the mineral has recently been analyzed again, abundant material for investigation being supplied by a specimen in the museum collection. This specimen is labeled "amesite and diaspore, Chester, Mass." in the handwriting of C. U. Shepard, and the label bears also the words "Coll. by E. Messia," by which is probably meant Macia, a French-Canadian, for many years foreman at the emery mine and an ardent collector of minerals. The specimen consisted of a large flat mass of diaspore showing pale grayish-pink cleavages several inches broad where broken and containing small cavities filled with interlacing needle-like crystals of diaspore. One side of the specimen is completely coated with a layer of flat amesite crystals of a pale green color somewhat iron stained. Scattered through the mass of the diaspore there are variously oriented crystals of amesite, large octahedrons of magnetite, and crystals of dark red to black rutile. The amesite occurs in tabular hexagonal crystals with dull prismatic faces. They reach an extreme diameter of 1 cm. with a thickness of 3 to 5 mm. By breaking up the diaspore, clean crystals were readily secured and these, when ground, were used for analysis. The material was perfectly homogeneous and free from impurities as shown by optical study.

The amesite has a uniform pale bluish-green color. The luster is pearly to somewhat metallic on cleavage surfaces. In thick pieces the mineral is translucent to almost opaque. Thin fragments are transparent. The powder is white with a very faint tinge of green. The mineral has a micaceous basal cleavage which, however, is not nearly so perfect as in most crystallized chlorites. Laminae are rather brittle and break in a manner suggesting a very imperfect prismatic cleavage. The hardness is about 2.3, as it scratches gypsum readily, but is scratched with great ease by calcite. The specific gravity as determined on approximately 3 grams of coarse fragments in a pycnometer is 2.77.

<sup>1</sup> Theil, Sitzungsberichte Akad. Wien, vol. 99, 1890, pp. 174-267.

Under the microscope cleavage plates of the amesite are dark in all positions between crossed nicols. Examined in convergent light a black cross is obtained, which separates slightly on rotation of the stage indicating that the mineral is biaxial with the axial angle,  $2V$ , very small, acute bisectrix normal to the perfect cleavage. The optical character is positive. The mineral is colorless as seen under the microscope. The refractive indices measured by the immersion method were found by Dr. E. S. Larsen to be as follows:

$$\begin{aligned}\alpha &= 1.597 \pm .003 \\ \beta &= 1.597 \pm .003 \\ \gamma &= 1.612 \pm .003 \\ \alpha - \gamma &= .015 \pm .003\end{aligned}$$

Heated before the blowpipe the amesite swells somewhat and exfoliates slightly becoming silvery brownish white in color. It is infusible. It does not become magnetic when roasted on charcoal. It yields considerable water in the closed tube. The main portion of the water is basic coming off only at a dull red heat. The mineral is partially decomposed by boiling in sulphuric, nitric, or hydrochloric acid with separation of flocculent silica. Upon analysis the pure powder yields the following results:

*Analysis of amesite from Chester, Massachusetts.*

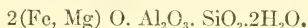
SiO <sub>2</sub> .....	20.95
Al <sub>2</sub> O <sub>3</sub> .....	35.21
FeO.....	8.28
CaO.....	.58
MgO.....	22.88
MnO.....	Trace.
H <sub>2</sub> O-110°C.....	.23
H <sub>2</sub> O+110°C.....	13.02
Total.....	101.15

This analysis yields the following simple ratios:

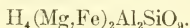
*Ratios of amesite from Chester, Massachusetts.*

SiO <sub>2</sub>	.3474	or	3.01	1×1.00
Al <sub>2</sub> O <sub>3</sub>	.3445	or	2.99	1×1.00
FeO	.1152	or	1.00	} 2×1.00
CaO	.5779	or	5.02	
MgO				
H <sub>2</sub> O	.7355	or	6.38	2×1.06

This gives the formula—



or Pisani's formula—



This analysis differs from that of Pisani only in the ratio of ferrous iron to magnesia. The definite ratio of MgO: FeO = 5:1 shown by this

analysis may be accidental and the percentages of these two oxides probably vary reciprocally in different specimens. The close agreement between the values found and the theoretical values is brought out in the following table:

*Analyses and calculated composition of amesite.*

	I.	II.	III.
SiO <sub>2</sub>	20.95	20.82	21.40
Al <sub>2</sub> O <sub>3</sub>	35.21	35.28	32.30
FeO	8.28	8.27	15.80
MgO (+CaO)	23.46	23.20	19.90
H <sub>2</sub> O	13.25	12.43	10.90
	101.15	100.00	100.30

I. Amesite, Chester, Massachusetts, analyzed by Shannon.

II. Amesite, values to conform with formula  $H_4(Fe_{1/6}Mg_{5/6})_2Al_2SiO_6$ .

III. Amesite, Chester, Massachusetts, analyzed by Pisani.

#### CORUNDOPHILITE FROM CHESTER, MASSACHUSETTS.

The name corundophilite was first given by Prof. C. U. Shepard to a chlorite occurring in association with corundum near Asheville, North Carolina. Later he referred to this species the chlorite which occurred abundantly in the emery vein of Chester, Massachusetts. Analyses by Genth and others have shown that the original North Carolina mineral is distinctly different from that of Chester, being essentially a low-iron prochlorite. The name corundophilite has since been reserved to the Chester chlorite. This mineral has been analyzed by Eaton, Pisani, and Obermayer, its optical properties have been given by Descloizeaux and Cooke, and its constitution has been discussed by Tschermak.<sup>1</sup> Despite the distinctness of the composition and optical properties of the mineral, it has been regarded dubiously by many mineralogists and has been variously referred to clinocllore, prochlorite, chloritoid, and biotite.

Corundophilite occurred very abundantly in the emery mine at Chester in large and small crystals and as granular and schistose masses. Hexagonal crystals often projected from the walls of narrow veins in emery and corundophilite crystals frequently were tipped with amesite in parallel position. Other minerals associated with the corundophilite include magnetite, ilmenite, rutile, margarite, and diaspore. The typical corundophilite has not been observed from any other locality.

The present examination of this mineral was undertaken in connection with the analysis of the associated amesite described in the

<sup>1</sup> For summary of previous work on this mineral and bibliography see Dana's System of Mineralogy, 6th edition, p. 655.

preceding paper. Abundant material for analysis was supplied from the Abert collection in the United States National Museum. The specimen (Cat. 20,289) was collected at the mine by J. T. Ames, after whom amesite was named. It consists of a mass of granular emery coated on one side with a layer of deep-green corundophilite crystals, over and around which is a layer of pearly diaspore. The individual corundophilite crystals reach an extreme diameter of 8 mm. with a length of 5 mm. They are greenish black in color, with deeply striated prismatic planes. The cleavage surfaces are clear and brilliant and do not display any metallic or pearly luster except where bruised or weathered. Selected clean crystals were ground for analysis and the analyzed powder was shown by optical study to be pure and free from inclusions. The analysis yielded the following results:

*Analysis of corundophilite from Chester, Massachusetts.*

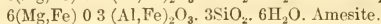
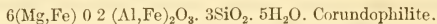
Constituents.	Per cent.
Silica (SiO <sub>2</sub> ).....	23. 20
Alumina (Al <sub>2</sub> O <sub>3</sub> ).....	24. 42
Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> )...	3. 48
Lime (CaO).....	1. 04
Magnesia (MgO).....	22. 76
Ferrous oxide (FeO)....	13. 40
Water (H <sub>2</sub> O).....	12. 00
Total.....	100. 30

This analysis serves to confirm those previously made upon corundophilite from this locality, and to indicate that the material here described is typical. It also indicates that this chlorite varies in composition within very narrow limits and emphasizes the difference between corundophilite and most other members of the group. The ferric oxide content is noteworthy, as it seems to have been overlooked by several previous analysts, total iron being calculated as ferrous oxide, and erroneous ratios were consequently obtained for univalent and trivalent oxides. The above analysis yields the following ratios:

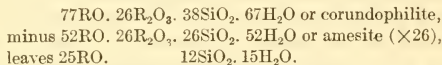
*Ratios of corundophilite.*

SiO <sub>2</sub> ...	.3847	38.47	3.85	3×.98
Al <sub>2</sub> O <sub>3</sub> ..	.2389	} 26.07	2.61	2×1.00
Fe <sub>2</sub> O <sub>3</sub> ..	.0218			
CaO....	.0185	} 76.95	7.70	6×.98
MgO...	.5645			
FeO...	.1865			
H <sub>2</sub> O...	.6661	66.61	6.66	5×1.02

These ratios may be compared with the amesite formula as follows:



Tschermak interpreted corundophilite as a molecular mixture of amesite and serpentine. In pursuance of this interpretation we may experimentally deduct from the ratios of column 2 above amesite equivalent to the total  $\text{R}_2\text{O}_3$ , thus:



The constituents remaining after deducting amesite then yield as ratios:

RO....	25	3.33	$3 \times 1.11$	$2 \times .96$
SiO <sub>2</sub> ...	12	1.61	$2 \times .80$	$1 \times .93$
H <sub>2</sub> O...	15	2.02	$2 \times 1.01$	$1 \times 1.16$

These ratios, considering the manner in which they were derived, are too close to those of serpentine to serve as evidence contradicting Tschermak's hypothesis. For reasons already stated, this line of speculation will not be further pursued at this place.

Optical examination has served to demonstrate the identity of the material analyzed with those examined optically by Descloizeaux and Cooke. The corundophilite is optically positive (+), biaxial with moderately large axial angle ( $\pm 60^\circ$ ). The bisectrix is inclined about 10 degrees, so that cleavage plates do not extinguish between crossed nicols and yield unsymmetrical interference figures in convergent light. The indices of refraction as measured by immersion are:

$$\begin{array}{l} \alpha = 1.600 \pm .003 \\ \beta = 1.603 \pm .003 \\ \gamma = 1.610 \pm .003 \\ \alpha - \gamma = .010 \pm .003 \end{array}$$

The pleochroism, which is marked, is as follows:

$$\begin{array}{l} \alpha = \text{deep blue-green.} \\ \beta = \text{deep blue-green.} \\ \gamma = \text{pale brownish green.} \end{array}$$

Corundophilite may be readily distinguished optically from amesite then by its large axial angle and the inclination of the bisectrix to the cleavage.

#### CHROMIUM-BEARING CHLORITE FROM CALIFORNIA.

A specimen recently transferred to the United States National Museum by the United States Geological Survey (Cat. 93602) shows coatings of a minutely scaly material of pale grayish-lavender color associated with fine emerald-green crystals of uvarovite on granular

masses of chromite. The specimen, which was collected by Mr. J. S. Diller, is from the mine of the Placer Chrome Company, 6 miles south of Newcastle, Eldorado County, California.

The coating of the lavender-colored chlorite is pure and is composed of microscopic crystals loosely aggregated, so that the masses are reduced to powder in an agate mortar by gentle pressure of the pestle. Such powder when examined optically was found to be homogeneous and free from included impurities. Upon analysis the following results were obtained:

*Analyses of chromiferous chlorite from California.*

	1 per cent.	2 per cent.	Average per cent.
Silica (SiO <sub>2</sub> ).....	29.48	29.24	29.36
Alumina (Al <sub>2</sub> O <sub>3</sub> ).....	18.81	.....	18.81
Chromic oxide (Cr <sub>2</sub> O <sub>3</sub> ) ...	1.80	1.26	1.53
Magnesia (MgO).....	35.82	35.52	35.67
Lime (CaO).....	1.94	2.46	2.20
Ferrous oxide (FeO)....	1.66	1.64	1.65
Water (H <sub>2</sub> O).....	11.34	.....	11.34
Total.....	99.60	.....	100.56

Column 3 of the above yields ratios as given in the following table:

*Ratios of chromium-bearing chlorite from California.*

SiO <sub>2</sub> ...	0.4869	48.69	5.01	5×1.00
Al <sub>2</sub> O <sub>3</sub> ..	.1841	} 19.42	2.00	2×1.00
Cr <sub>2</sub> O <sub>3</sub> ..	.0101			
MgO...	.8847			
CaO...	.0392	} 94.68	9.75	10× .98
FeO...	.0229			
H <sub>2</sub> O...	.6294	62.94	6.38	6×1.06

The formula derived from the analysis may then be compared with the commonly accepted formula for clinochlore as follows:

10RO..	2R <sub>2</sub> O <sub>3</sub>	5SiO <sub>2</sub>	6H <sub>2</sub> O	California mineral. Clinochlore (Dana).
10RO..	2R <sub>2</sub> O <sub>3</sub>	6SiO <sub>2</sub>	8H <sub>2</sub> O	

Despite the deficiency in silica and water shown by the above ratios, the analysis is similar to many which have previously been referred to the kammererite variety of clinochlore.

Under the microscope the powder is seen to be made up of well-defined hexagonal scales or prismatic aggregates of scales which appear colorless in ordinary light. Basal scales are dark in all positions between crossed nicols, so that the mineral is probably, like most chlorites, biaxial with the axial angle approaching zero, acute bi-

sectrix normal to the perfect cleavage. Individual scales are too small to yield an interference figure in convergent light. The optical character is positive, the indices of refraction as determined by immersion being:

$$\begin{aligned}\alpha &= 1.582 \pm .003 \\ \beta &= 1.582 \pm .003 \\ \gamma &= 1.593 \pm .003 \\ \alpha - \gamma &= .011 \pm .003\end{aligned}$$

#### CHROMIUM-BEARING CHLORITE FROM WYOMING.

Several specimens recently received at the United States National Museum by transfer from the United States Geological Survey consist of granular chromite containing veins and disseminated crystals of a deep purplish red chlorite. The locality from which these specimens were obtained is given as Deer Park, Wyoming. Individual crystals of the chlorite reach a maximum diameter of 1 cm. and are somewhat crumpled as from pressure. Aside from the chromite which makes up the bulk of the specimens, the only associated mineral is a brilliant green clayey substance which lines cavities in the specimens. This mineral, which is doubtless wolchonskoite, is not present in sufficient amount for analysis.

By careful hand picking the chloritic mineral was obtained for analysis free from all but a very little chromite, which under the microscope was seen to occur as minute grains between the folia of the chlorite itself. Upon analysis of this selected material the following results were obtained:

#### *Analysis of chromium-bearing chlorite from Wyoming.*

Chromite.....	2.04
Silica (SiO <sub>2</sub> ).....	32.12
Lime (CaO).....	1.24
Ferrous oxide (FeO).....	1.98
Magnesia (MgO)...	35.36
Alumina (Al <sub>2</sub> O <sub>3</sub> )..	9.50
Chromic oxide (Cr <sub>2</sub> O <sub>3</sub> ).....	7.88
Water (H <sub>2</sub> O).....	10.25
Total.....	100.37

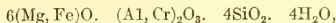
This analysis yields the following ratios:

#### *Ratios of chlorite from Wyoming.*

SiO <sub>2</sub>	.5327	53.27	4 × .93
Al <sub>2</sub> O <sub>3</sub>	.0930	14.48	1 × 1.00
Cr <sub>2</sub> O <sub>3</sub>	.0518		
MgO	.8770		
CaO	.0221	90.67	6 × 1.06
FeO	.0276		
H <sub>2</sub> O	.5689	56.89	4 × 1.00



The ratios derived from the analysis then yield the formula:



which may be compared with the clinochlore formula as follows:

6RO	R <sub>2</sub> O <sub>3</sub>	4SiO <sub>2</sub>	4H <sub>2</sub> O	Wyoming chlorite.
5RO	R <sub>2</sub> O <sub>3</sub>	3SiO <sub>2</sub>	4H <sub>2</sub> O	Clinochlore (Dana).

This, like the preceding chromium bearing chlorite from California while differing from the formula usually assigned to clinochlore, is similar to several chrome-chlorites which have been referred to kammererite or kotschubeite.

Under the microscope the present mineral is biaxial and negative, with a very small optic axial angle, and having the acute bisectrix normal to the perfect cleavage. Basal plates are dark in all positions between crossed nicols. The indices of refraction are:

$$\begin{aligned}\alpha &= 1.587 \pm .003 \\ \beta &= 1.590 \pm .003 \\ \gamma &= 1.590 \pm .003 \\ \alpha - \gamma &= .003 \pm .003\end{aligned}$$

The mineral is distinctly pleochroic, the scheme being:

$$\begin{aligned}\alpha &= \text{pale red purple.} \\ \beta &= \text{red purple.} \\ \gamma &= \text{red purple.}\end{aligned}$$

Under existing classifications both the above chromium-bearing chlorites would be referred to clinochlore, or to the chromium-bearing varieties kammererite and kotschubeite. These two examples serve to illustrate the wide variation, not only in chemical composition, but also in indices of refraction which may exist between different specimens now included under the same species. It is highly desirable that optical properties, especially refractive indices, be in all cases determined upon analyzed material if work on minerals of this sort is to be made of any value in the interpretation of isomorphous relationships.